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Virginia Air Quality: Trends, Exposure, and Respiratory Health Impacts

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ABSTRACT

Air quality is an important determinant of public health and quality of life. A secondary data analysis was carried out to investigate trends and air quality in Virginia. The analysis included an evaluation of two major air pollution source categories, emission of criteria and hazardous air pollutants, ambient concentrations of criteria pollutants, ozone standard violations and associated meteorology, and hospital admissions for asthma and chronic obstructive pulmonary disease in Virginia. Comparisons were also made to national trends and statistics. Data was gathered from many open reputable on-line sources available through various state and federal agencies. Virginia routinely meets 5 of the 6 criteria air pollutant ambient standards. Ozone does continue to represent a challenge for Virginia, as it does for many other states. Potential focus on further production and consumption of renewable energy, improvement in fuel efficiency among SUV's and light trucks, reduction of the metals content in fuels burned by electric utilities, utilization of emissions inspections for automobiles, utilization of vapor recovery systems at gas stations, and continued emphasis on ozone precursors all have the potential to further improve air quality within Virginia. This is important because the very young and the elderly are particularly vulnerable to the adverse effects of poor air quality.

INTRODUCTION

Poor air quality has long been associated with adverse human and ecological health impacts. For example, poor air quality led King Edward I in 1273 to prohibit the burning of coal due to noxious air emissions (Beck 2007). Although we have made significant progress in controlling air pollution in many developed countries today, concern still exists regarding the impact of air quality on health. In the 1980's and 1990's, several epidemiologic research studies showed that in the United States both particulate matter (Wilson and Spengler 1996) and ozone (Lippmann 1989) were associated with adverse human health effects at levels typical of that time. Additional

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studies were conducted and this body of research is now reflected in the United States Environmental Protection Agency's (USEPA) Criteria Documents required under Title I of the Clean Air Act (USEPA 2014a; USEPA 2010). These Criteria Documents form the basis for the compliance levels set under the National Ambient Air Quality Standards (NAAQS).

Today in the Unites States, the USEPA regulates ambient air quality through six NAAQS. The Criteria Air Pollutants regulated under Title I of the Clean Air Act are particulate matter (PM), carbon monoxide (CO), ozone (O_3), oxides of sulfur (SO_x), oxides of nitrogen (NO_x), and lead (Pb). The particulate matter standards include both particles under 10 microns in aerodynamic diameter (PM10) and particles under 2.5 microns in aerodynamic diameter (PM2.5). Ambient levels of these Criteria Air Pollutants and other ambient air pollutants are measured continuously through several of USEPA's extensive ambient air monitoring networks, including the State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), Special Purpose Monitors (SPMS), and Photochemical Assessment Monitoring Stations (PAMS) (USEPA 2015a). In addition, emissions of the six criteria pollutants are tracked through the National Emissions Inventory (NEI). The USEPA utilizes state inventory data to compile the NEI on an annual basis and conducts a more comprehensive NEI review of the state inventories every three years. Hazardous air pollutants (HAPs) are also regulated by the USEPA through several programs. One of these programs created by the Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313 created the Toxic Release Inventory (TRI) program and contains a list of roughly 650 chemical compounds, many of which are HAPs. HAPs, in addition to waste water and solid waste toxics, are tracked through the TRI (USEPA 2015b), which is a multi-media inventory system designed to fulfill requirements under EPCRA. Trends in the release of HAPs can be tracked by industrial sector and by geographic region through the TRI.

In addition to the actual measurement of airborne concentrations of pollutants and an inventory of air pollution releases, significant sources of air pollution can be tracked through various databases. Two industrial sectors that are particularly important contributors to ambient air pollution are the energy sector and the mobile source (e.g. automobiles) sector. The Energy Information Administration (EIA) (www.eia.gov) is a semiautonomous agency within the US Department of Energy that tracks trends and makes projections of energy production and use in the United States and within individual states. Many state Department of Transportation (DOT) agencies carefully track mobile sources by compiling data on automobile and truck use throughout their state. Mobile source data such as the number of vehicles, total vehicle miles traveled, and fuel efficiency statistics of the motor vehicle fleet are compiled by most state DOTs and the EIA. This information can be used to assess the impact of these two important sectors on ambient air quality.

We endeavored to utilize the information described above to investigate trends in important air pollution sources (energy and mobile sources), TRI data, NEI data, and ambient measurements made by SLAMS monitoring sites for the state of Virginia and explore potential contributors to human exposure and risks of chronic respiratory disease.

METHODS

The approach to assessing the current air quality condition and trends in Virginia were accomplished through secondary data analysis. The overall time period covered in this analysis was from 2002 through 2013, but varied by each analysis due to the varying availability of different data sources across different time periods.

Data Collection

Data from the National Emissions Inventory (NEI) and the Toxics Release Inventory (TRI) were directly accessible via the USEPA website. NEI data was downloaded directly from the Office of Air Quality Planning & Standards, Emissions Inventory & Analysis Group, Technology Transfer Network Clearinghouse for Inventories & Emissions Factors data page (USEPA 2015c). The most recent NEI data available was from 2011. The TRI data was searched and downloaded directly using the USEPA TRI Explorer search tool (USEPA 2014b). Data on energy production and use was downloaded directly from EIA via their State Energy Data System (SEDS) search tool accessible on-line (EIA 2015a). Motor vehicle statistics were accessed through official state data reports published by the Virginia Department of Transportation (VADMV 2014) and through the EIA Monthly Energy Reviews (EIA 2015b). Ambient air monitoring data was accessed through Virginia Department of Environmental Quality (VADEQ) official annual air quality data reports (VADEQ 2009, 2010, 2011, 2012, 2013, 2014). In addition, ozone exceedance day data for the years 2008 – 2013 was obtained directly from the VADEQ Air Quality Monitoring branch (VADEQ personal communication, 2/6/15). The VADEQ reports are based on measurements made by the VA SLAMS monitoring sites. Meteorological data for the years 2008 – 2013 was obtained directly for four Quality Controlled Local Climatological Data (QCLCD) NOAA weather stations located throughout the state of Virginia for Central, Southeastern, Southwestern, and Northern areas of the state (Farmville, Hampton, Martinsville, and Manasas, respectively) (NOAA 2014). Data on asthma admissions was abstracted from a state report by the Virginia Department of Health, Division of Environmental Epidemiology pilot project on Environmental Public Health Tracking published in 2012 (VDH 2012). Asthma data was also collected from the Centers for Disease Control and Prevention by analyzing Morbidity and Mortality Weekly Reports (CDC 2011), Data Briefs and raw data through the Chronic Indicator Search Tool (CDC 2011, 2012a, 2012b, 2015). Other key asthma data was collected from the Virginia Asthma Plan 2011 – 2016 report (Kiger 2010), Virginia Department of Health Burden report for 2013, and American Lung Association Report for 2014 (American Lung Assoc 2014).

Data analysis

First, the data was simply described over the time period and observations regarding any patterns or trends were noted. Second, comparisons were made between trends in Virginia and national trends in order to identify differences. Third, the number of days with a violation of the NAAQS for ozone in each “ozone season” for the years 2008 through 2013 was analyzed. A more detailed description of ozone violations was also described in relation to the meteorology measured in central Virginia. The meteorological parameters investigated included dry bulb temperature and % relative humidity. Comparisons between the seasonal average of the meteorological parameters and the number of NAAQS ozone violations from 2008 through 2013 was assessed.

Fourth, we described data on hospital admissions for asthma and chronic obstructive pulmonary disease (COPD). Detailed description of asthma admissions by age group, with a particular focus on the elderly (> 65 years of age) and young children (<5 years of age) was also performed. This analysis was descriptive in nature and further statistical assessment will be conducted in the future.

RESULTS & DISCUSSION

Sources of Ambient Air Pollution

a) Energy Sector

Analysis demonstrated that for many energy sources, Virginia reflected the national trends. Overall energy consumption measured in terms of either British Thermal Units (BTUs) or in terms of physical quantities (e.g. short tons for coal) had similar trends and showed a decline in the 2008 – 2009 time frame in both the statewide and national consumption trends. This is likely the result of changes in the economy and the impact of the recession that began in 2007. Energy consumption has since returned to pre-recession levels and will likely continue to increase. Nuclear energy consumption has remained relatively flat and unchanged since 2002 in both the statewide and national data as the number of nuclear power plants has remained the same over many years. However, there are plans to potentially build more nuclear power plants in the future and if these plants were built, it would impact the available energy from this sector. Coal exhibits similar trends to overall energy consumption, with the exception that after the recession and recovery in 2010 there was an increase in consumption but this increase began to wane in 2012. At the same time, as hydraulic fracturing has made natural gas more plentiful and hence cheaper, there has been an increase nationally in natural gas consumption and this may have displaced some of the coal used nationally and statewide. The upward trend for natural gas consumption is even more pronounced in Virginia (Figure 1). The percent change from baseline in Figure 1 is approximately an 11% increase from baseline in consumption of natural gas nationwide, whereas in Virginia there is roughly a 59% percent increase from baseline. This may benefit the air quality nationally and in Virginia because natural gas burns significantly cleaner than coal and is much less carbon intensive on a per BTU basis.

Interestingly, Virginia does lag behind the national trends in terms of renewable energy consumption. There was a dramatic rise in renewable energy consumption on the national level with a substantial increase beginning in 2008 and continuing after the economic recovery. However, Virginia appears to be relative flat across the time frame analyzed (Figure 2). An assessment of Virginia's renewable energy production and consumption shows that while consumption flattens out, there is a decrease in production via renewable energy after 2005 (Figure 3).

b) Automobiles and mobile sources

Mobile sources are very important in air quality inventories. Trends in automobile use in Virginia reflect national trends, where from 2002 through 2012 there has been an increase in the number of registered vehicles and an increase in vehicle miles traveled (VMT) but this trend has not been dramatic and in 2007 (national trend) and 2008 (Virginia) there was an inflection point where VMT seems to have leveled off or even decreased slightly. In Virginia, there were 6,659,560 vehicles registered in 2002 and 7,706,795 vehicles registered in 2012 (VADMV 2014). This represents a growth of approximately one million registered vehicles in Virginia over these 10 years.

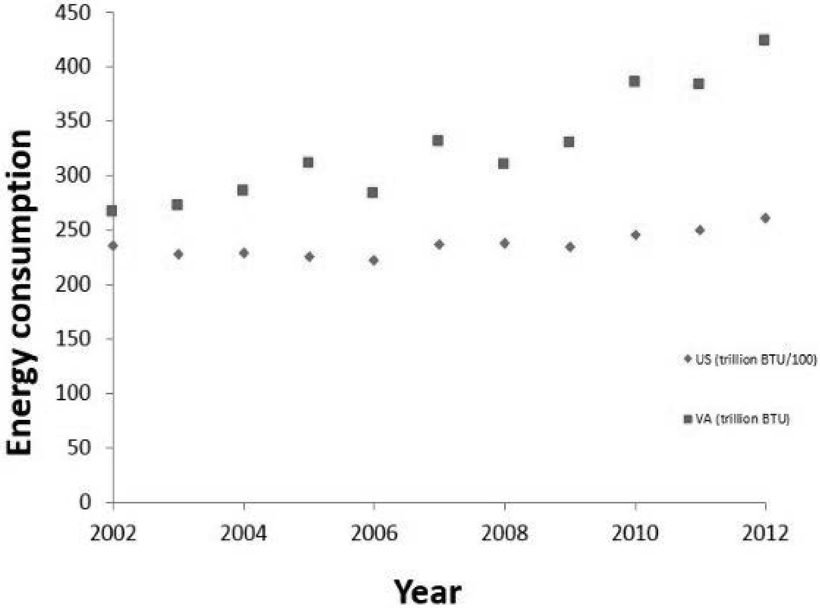

FIGURE 1. Natural Gas Consumption trends for Virginia and Nationally from 2002 - 2012.

Vehicle miles traveled (VMT) is an important parameter to understand the potential contribution of mobile sources to air pollution. In Virginia the peak year for VMT was 2008 with 82 billion miles traveled (VADMV 2014) and 2007 was the peak year nationally with roughly 3 trillion miles traveled (McCahill and Spahr 2013). In Virginia, VMT has leveled off at roughly 81 billion miles. The leveling off of VMT both nationally and statewide is likely related to several important trends that transportation officials believe will continue to retard dramatic growth in VMT with the current technologies. These trends include general economic activity and unemployment rates, the aging of the baby boom generation, saturation of automobile ownership per household, higher costs of car maintenance, decreased desire to drive due to increased traffic congestion and commute times, and changes in attitudes about living in more densely populated communities (McCahill and Spahr 2013). While these changes have taken place, some improvements in fuel efficiency have also taken place. Light duty vehicles (short wheel base, e.g. sedan) have increased their average fuel efficiency from 22 miles per gallon (MPG) in 2002 to 23.3 MPG in 2012 (EIA 2015b). However, light duty vehicles with long wheel bases (e.g. SUVs) have actually seen a slight decrease in their fuel efficiency from 17.5 MPG in 2002 to 17.1 MPG in 2012 (EIA 2015b). Heavy duty trucks have seen a slight increase in fuel efficiency from 5.8 MPG in 2002 to 6.4 MPG in 2012 (EIA 2015b).

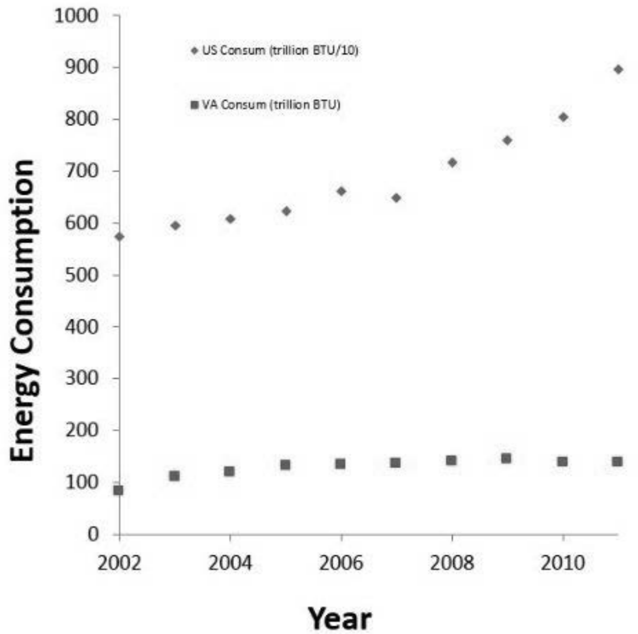

FIGURE 2. Renewable energy consumption trends in Virginia and Nationally from 2002 - 2011.

This data represents a mixed result in terms of benefits for air quality. Leveling off of VMT is beneficial and certainly improvements in fuel efficiency standards for light duty short wheelbase vehicles will result in reduced air pollution from mobile sources. However, the popularity of light duty long wheelbase vehicles (SUVs, light duty trucks) and their relative decrease in fuel efficiency will likely offset some of the air quality gains made in the mobile source sector.

c) Toxic Release Inventory (TRI)

Data gathered from the USEPA TRI demonstrated that in general the trends of total Hazardous Air Pollutants (HAPs) emitted among different industries in Virginia were similar to national trends. The only exceptions were North American Industrial Classification System (NAICS) code 313/314 Textiles, NAICS 333 Machinery, and NAICS 4247 Petroleum Bulk Terminals, which appeared to show a drop in Virginia and yet a relatively flat pattern nationally. In particular, the NAICS 333 Machinery industrial sector showed a significant drop in HAP emissions after the start of the recession in Virginia and has not returned to pre-recession levels.

Analysis of this TRI data showed that in both Virginia and nationally the electric utilities industry (NAICS 2211) emitted the highest amount of TRI-listed hazardous air pollutants. A total of 4,580,961,573 lbs of TRI-listed HAPs were released off-site from electric utilities nationally from 2003 through 2012 and a total of 120,890,122 lbs were

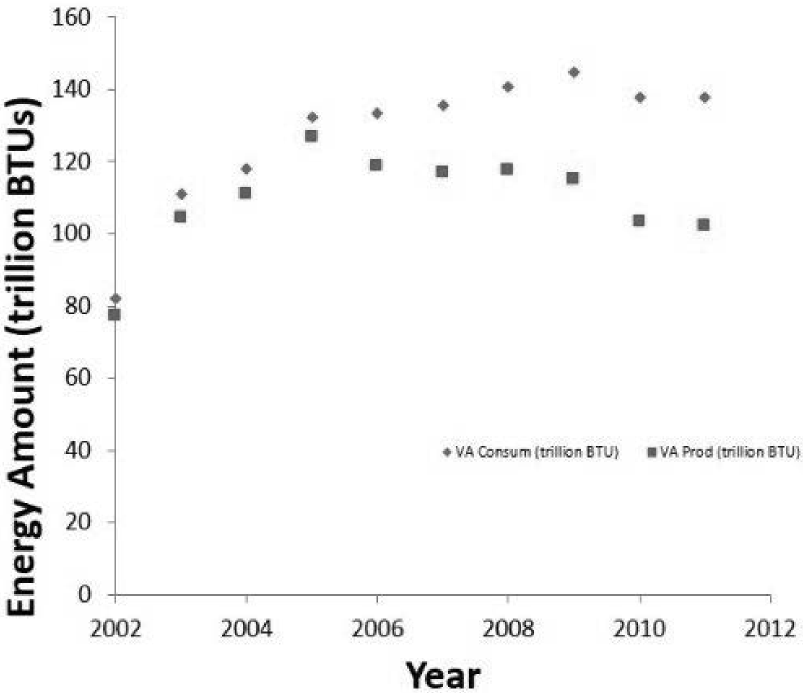

FIGURE 3. Virginia renewable energy consumption versus production 2002 - 2011.

released from Virginia utilities over the same time period. The EIA has a data utility tool available on-line (EIA 2015c) which produces estimates of the net generation capacity at electric utilities. It was found that 17,719,561,000 megawatts was the net generation of all US electric power utilities in NAICS category 22 from 2003 through 2012 and 333,683,000 was the net capacity produced in Virginia over the same time frame. By extension, it was found that the TRI-listed HAPs emission rate averaged over the period from 2003 through 2012 on a per megawatt basis can be calculated as 259 lbs of HAPs per megawatt in the US overall and 362 lbs of HAPs per megawatt in Virginia. As a result, it appears for the 10 year period cited that Virginia had a higher HAPs emission rate on a per megawatt basis compared to the country as a whole. It is important to note that this analysis was conducted only considering fossil fuels and biomass, in other words only fuels that are burned to generate electricity. Nuclear and renewable sources were not included because it was believed that they would not contribute significantly to the TRI-listed HAP emission rate and therefore their exclusion provides a more accurate accounting of the true per megawatt emission rate from electric utilities that are likely to have TRI-listed HAP emissions. The mix of combustible fuels in the energy portfolio for Virginia electric utilities closely mirrors that of the US as a whole and therefore differences in fuel mix are not likely an explanation for the higher emission rate in Virginia (Figure 4).

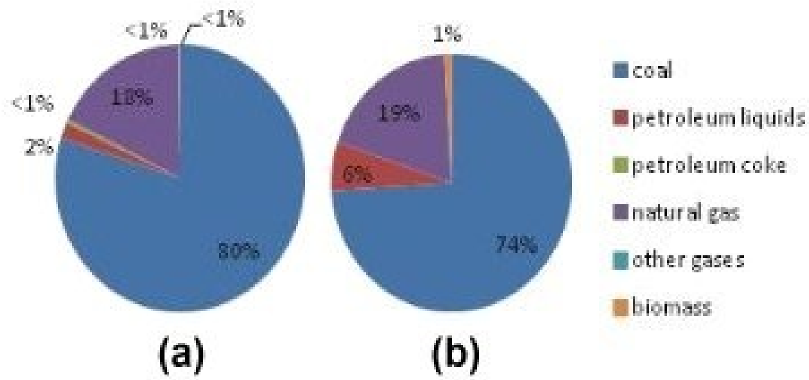

FIGURE 4. Average combustible fuel mix for the United States (a) and Virginia (b) as a percent of total Megawatts generated from 2003 - 2012.

The combustible fuel mix likely explains the finding that the two most abundant TRI-listed HAPs released in Virginia are “magnesium and its compounds” and “lead and its compounds”. Overall, magnesium, lead, and their related compounds represented 52 % to 77% of the total mass of TRI-related emissions from 2003 through 2013. TRI data showed that there were anywhere from 79 to 90 different compounds in the TRI database over this time period, but that in many cases, the top 5 compounds on the TRI list for Virginia were metals. This likely resulted from the fact that these metals frequently are present in trace quantities in the fuels burned by electric utilities. A trace concentration in fuels can translate into a large amount of the TRI-listed material being emitted over time because of the massive quantity of fuel that is burned by utilities. The most common organic compounds reported were solvents or additives and the exact chemical varied year to year but included methanol, toluene, 2,4-dinitrotoluene, ethylene glycol, and n-hexane. Toluene was the most common organic in Virginia and was reported in the third or fourth largest quantity of all TRI-listed HAPs for 6 of the 10 years analyzed.

d) National Emissions Inventory (NEI)

The NEI demonstrated several interesting characteristics about air quality trends. The relative contribution of the different source categories were similar from the 2008 inventory to the 2011 inventory and relative source contributions were similar for SO_2 and NO_x in Virginia and the United States overall. The NEI demonstrated the importance of the transportation sector in contributing to NO_x emissions both statewide and nationally.

Differences were observed between Virginia and national trends in the relative contributions among sources of both PM10 and PM2.5. For example, the stationary source combustion sector (e.g. electric utilities), transportation, and industrial processes contributed a higher percentage of emissions in Virginia compared to the national inventory (Figure 5). In addition, the NEI also demonstrated that the relative source contribution from the transportation sector was more substantial for the CO and volatile

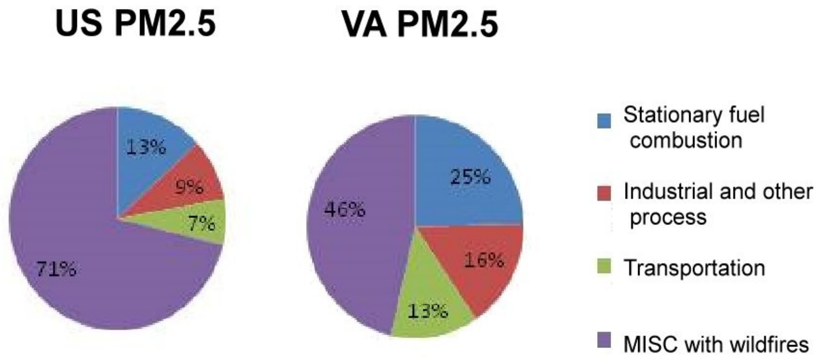

FIGURE 5. Source contribution to PM 2.5 emissions in 2011 for the United States and Virginia based on NEI. Includes both filterable and condensable particulate matter.

organic compound (VOC) emissions in Virginia compared to the overall national trend. (Figure 6) This may be a consequence of the lack of emissions testing for motor vehicles, including fuel system leaks and tail pipe testing, and the lack of vapor recovery systems at gas stations in Virginia. Alternatively, this simply could be an artifact of the inventory where there was a smaller contribution from wildfires in VA compared to the United States as a whole.

National Ambient Air Quality Standards (NAAQS) Compliance

a) Overview – Criteria Air Pollutants in Virginia

A review of the annual ambient air quality monitoring reports from the Virginia Department of Environmental Quality (VADEQ 2009, 2010, 2011, 2012, 2013, 2014) reveals that between 2008 and 2013 the state was in compliance with the NAAQS for carbon monoxide, nitrogen dioxide, and sulfur dioxide. Virginia was in compliance with the particulate matter NAAQS for PM10 from 2008 through 2013 and had only one violation of the PM2.5 twenty four hour standard in 2013. However, it is important to also note that Virginia applied for and received an exceptional event exemption in 2008 and 2011 because high particle concentrations were caused by the coastal North Carolina and Dismal Swamp wildfires. Therefore, these events are not recorded as violations of the NAAQS because the USEPA excluded these particle exceedances from consideration. Despite this petition, it is important to note that these wildfires resulted in significantly elevated particle concentrations and future wildfires may impact public health.

Ozone is the criteria pollutant where there is a persistent challenge in meeting the NAAQS standard for Virginia, as is the case for many areas in the United States. Northern Virginia, Richmond, and the Hampton Roads areas are generally the most problematic areas and experience the highest number of days with a violation of the NAAQS, commonly termed an exceedance day. Ozone is a secondary pollutant and as such its formation is greatly affected by the meteorological conditions and the

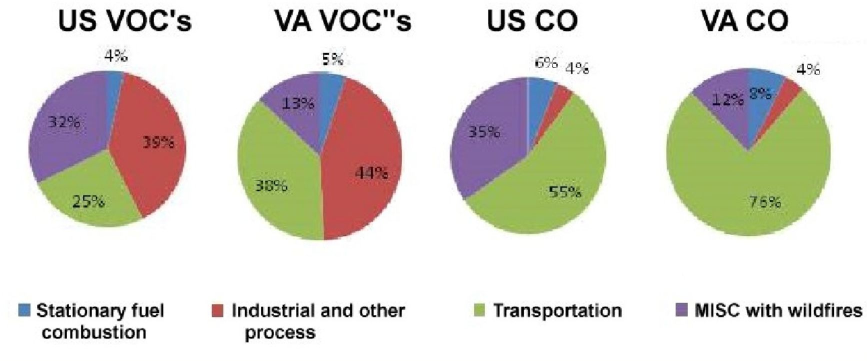

FIGURE 6. Contribution of transportation sector to carbon monoxide (CO) and volatile organic compound (VOC) emissions in the Unities States and Virginia based on 2011 NEI.

concentrations of precursor chemicals. As a result, it is suspected that the differences in the ozone exceedance trends observed across Virginia for the years 2008 through 2013 are significantly related to these factors, which has some similarities to national trends. (Figure 7)

b) Ozone excursions 2008 – 2013

For the period of 2008 through 2013, there were 95 days where at least one monitor in Virginia exceeded the NAAQS for ozone. The data in Figure 7 represents a total of 171 "hits" for the 95 days where there were ozone exceedances, where a "hit" is a day recorded in a given region where there was at least one monitor in the region that exceeded the 8-hour average NAAQS of 0.075 ppm of ozone. There are many days where more than one region exceeded the standard on the same day, so each exceedance day can have more than one "hit". Ozone is a regional pollutant with highly correlated concentrations across different regions and therefore it is not unusual to have multiple "hits" on one day. In addition, there are multiple monitors in each region, so the 171 "hits" represents a total of 358 measurements among all monitors in all regions that recorded an ozone concentration value above the NAAQS standard for the period 2008 through 2013. As a result, each statewide exceedance day often has multiple hits across different regions with many different monitor measurements. The ozone daily standard also records ozone as an 8 hour rolling average based on 8 hourly average measurements from continuous monitors. In other words, the time period from 00:00 to 08:00 is one rolling average, then 01:00 to 09:00 is the next 8 hour rolling average in the 24 hour period, and so on. There are a total of 24 eight hour rolling averages in any given 24 hour period as EPA includes averages over the nighttime as well as daytime. If there are multiple 8 hour rolling averages that exceed the standard, EPA NAAQS stipulate that that this only constituents one exceedance day recorded as the highest 8 hour rolling average of all measurements in the 24 hour period.

Air monitoring data shows that of the 95 ozone exceedance days in Virginia between 2008-2013, 85% of all exceedance days occurred between the months of June

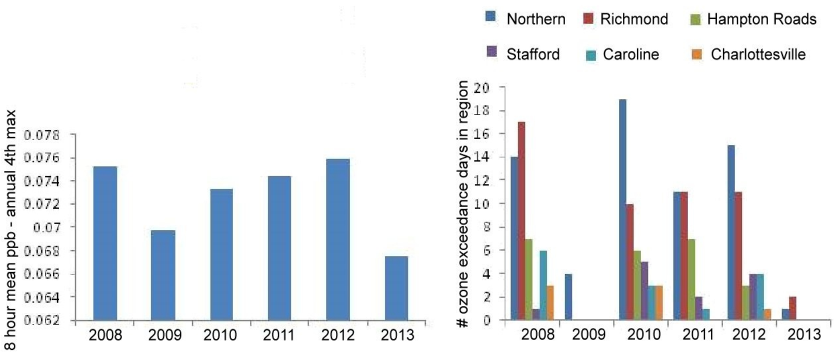

FIGURE 7. National trends in ozone concentrations by year (left) and # ozone exceedance days in Virginia (right) from 2008 through 2013. Note decrease in 2009 and 2013 in both national trends and Virginia trends.

through August and the peak month was July (Figure 8). The highest concentration of ozone measured between 2008 – 2013 was 0.110 ppm at the Henrico monitoring site in Central Virginia (Richmond area) and occurred on June 6, 2008.

If the exceedance data is broken down and summarized by the daily period for which the 8 hour rolling average is calculated, it can be shown that the critical window for ozone exceedance is from 9 am through 7 pm during the day, where more than roughly 98% of the exceedance measurements had at least some percentage of their measured time in this critical window. This is not surprising because ozone is a photochemical oxidant formed in the presence of sunlight. However, there were a small percentage of measurements (~1.5%) collected overnight that were completely outside this critical window. This finding suggests that the persistence of ozone on high concentration days can occur from the lag time associated with transport of ozone generated during the daytime to other regions after dusk resulting in a small number of violations during the night. In fact, one of the ozone violations that occurred from 11 pm through 7 am occurred on April 18, 2008 at the monitoring station in Madison County Virginia, which is a town close to Charlottesville at the foothills of the Blue Ridge Mountains. Data shows earlier in the day on April 18th that there were widespread violations of the standard across all regions of Virginia as the day was unusually warm (avg daily temp 84 ^{0}F) and weather data from the meteorological station at Charlottesville-Albemarle airport (approx 24 miles from Madison) shows that the predominate wind direction for the day and specific periods overnight was from the south-southeast, suggesting that ozone generated during the day throughout Virginia was transported north to Madison County Virginia resulting in the violation overnight. It can be speculated that while ozone is not generated in the absence of sunlight, that it does take some time for ozone that is generated during the day to degrade and therefore it can persist into the evening.

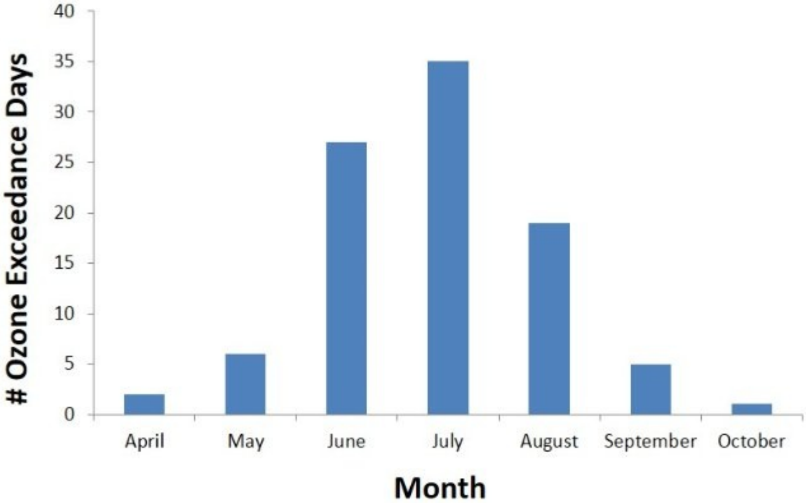

FIGURE 8. Ozone exceedance days in Virginia by month for 2008 through 2013.

c) Meteorological Assessment 2008 – 2013

Meteorological data captured by the NOAA Quality Controlled Local Climatological Data (QCLCD) system was summarized from May to September for the years 2008 – 2013 in the central Virginia region (Farmville meteorological station; approximate center of state). In this descriptive analysis, average daily temperatures between 8 am and 8 pm and the average percent relative humidity (% RH) were calculated for each year's May through September period. Data on ozone violation data in central Virginia was also summarized by including all central Virginia air quality monitors, which were located in Albemarle County, Rockbridge County, Chesterfield County, Henrico County, Hanover County, Charles City County, and Caroline County. The recording of ozone violations are highly correlated among these different monitors because ozone is a regional pollutant and they are all located in the same approximate region. The ozone exceedances for the period were then characterized by using the data from the monitor with the maximum number of ozone exceedance days during the period. This was compared over each year of analysis (Table I). Correlation coefficients calculated for the maximum number of exceedance days in a period versus the number of days where the temperature was greater than 90 ^{0}F was 0.59 and for days with high relative humidity was -0.73. Days that are greater than 90 ^{0}F are associated with intense sunlight and likely associated with factors conducive to photochemical reactions and likely explains the positive correlation coefficient. Days that have a high relative humidity, defined here as between 80% and 95%, are likely to occur when weather conditions are less conducive to photochemical reactions, and hence explains the negative correlation coefficient. In fact if the %RH goes above these values it will most likely produce a rain event.

TABLE 1. Ozone violation data in Central Virginia and corresponding average meteorologic conditions for the May through September time period from 2008 – 2013.

Year	Max # vio* measured by any given monitor	# 90^0F days	# days RH 80-95%
2008	11	62	71
2009	0	44	115
2010	6	88	71
2011	7	62	105
2012	5	69	75
2013	1	37	112

* - violation days

Exposure & Health Effects

a) Overview

Chronic respiratory disease trends in Virginia and Hampton Roads

The prevalence of asthma is a concern nationwide, given that an estimated 8% of Americans have asthma (CDC 2011a). This percentage translates to around 25 million individuals in the United States (US) who are known to have asthma. Of these 25 million individuals, 7 million are children (VDH 2013). Asthma cost the US $56 billion dollars in 2010. However, the estimated prevalence of asthma is higher in Virginia and, even more so, in Hampton Roads. The most recent data available indicate that over 9 percent of Virginians have asthma (Kiger 2010) which translates to an estimated 163,252 pediatric asthma cases and 553,864 cases of adult asthma (American Lung Association 2014.). From 2000-2008, the adult female rate of 11.9 percent surpassed adult male rate of 6.5 percent (consistent with national trends). In addition, those with the lowest income and education had the highest rates of asthma. An increase in lifetime asthma rose from 9.3 percent in 2003 to 14.4 percent in 2008 for children of Virginia. (CDC 2012a, 2012b)

Prevalence rates in Norfolk, Chesapeake, and the Peninsula are much higher and range from 11% to 12%. Hospitalizations for the condition result in a length of stay of 4 days and cost nearly $13,000 on average. Such asthma related hospitalizations represent the fourth leading cause of hospitalization among children in Virginia (Kiger, 2010).

COPD

The prevalence of COPD in Virginia is 5.7 percent, which was equal to the national rate in 2012 among adults $\geq$18 year of age. The prevalence of COPD in 2012 among those adults $\geq$45 years of age and older in Virginia is 9.3 percent, which was greater than the national rate 9.0 percent. Prevalence of current smoking among adults ≥18 years of age with diagnosed COPD in 2012, was 48.3 percent for Virginia and 47.0 percent for the national rate. Prevalence of current smoking among adults ≥45 years of age with diagnosed COPD in 2012, was 42.0 percent for Virginia and 38.6 percent for the national rate. The following groups were more likely to report COPD: persons aged 65–74 years, non-Hispanic whites, women, individuals who were unemployed, retired, or unable to work, individuals with less than a high school education, people with lower incomes, individuals who were divorced, widowed, or separated, current or former smokers, and those with a history of asthma (CDC 2011b, 2015).

b) Asthma admissions in Central VA by age group

A pilot Environmental Public Health Tracking (EPHT) project conducted by the Virginia Department of Health in 2011 investigated the relationship between weather patterns and asthma admissions in the metro Richmond area (VDH 2012). This project found that there was an association between daily diurnal temperature and asthma admissions but this relationship had a negative correlation coefficient (VDH 2012), likely due to the fact that the peak in asthma admissions to the hospital occurred in September and October (cooler months) and was the lowest in the middle of the summer (hottest months). It is well documented that asthma hospital admissions peak, especially for children, in the early fall due to the on-set of molds from decaying plant matter and also due the increase in the transmission of respiratory infections among children returning to school (NJDHSS 2006). While the overall rate of hospital asthma admissions is lowest in the summer, studies conducted in locations outside of Virginia have estimated that summer time ED admissions are likely to be 28% higher on summer days with elevated ozone concentrations (Weisel and Cody 1995). Further study that distills the effects of multiple triggers of asthma exacerbation needs to be conducted in Virginia to determine the true relationship between hospital admission and ambient air quality.

The VDPH pilot project also documented the hospital admission rate for asthma as a primary diagnosis among different age groups. Their data analysis showed that children under the age of 5 have the highest admission rate for asthma followed by children between the ages of 5 and 9 (VDH 2012). They also showed that the elderly, especially those over 70 years old, had an elevated incidence of asthma admissions (VDH 2012). This suggests that those most at risk for hospital admission due to asthma are likely the young and old in the population. By extension, an argument could be made that these are also the most at risk from the adverse effects of poor ambient air quality. Differences in asthma admission rates are noted between the years 2008 (high ozone year) and 2009 (low ozone year) in Virginia but it is variable, with 0-4 year olds having a higher rate in 2008 versus 2009 and 5-9 year olds having a higher rate in 2009 versus 2008 (VDH 2012). One could speculate that the rate among school age children is more influenced by triggers like respiratory infections and toddlers who are not yet attending school may have their rates more strongly impacted by ambient air quality triggers. A more detailed investigation of this data is warranted.

SUMMARY

This secondary data analysis helped to demonstrate several characteristics about the condition of Virginia's ambient air quality and factors that impact this quality. The large increase in use of natural gas for energy in Virginia will likely contribute to improved air quality. The national trend in decreasing fuel efficiency for popular long wheelbase vehicles, such as SUVs and light trucks, will likely negatively impact all states, including Virginia. Some additional improvements that may contribute to better air quality in Virginia could include an enhanced focus on better production and consumption of renewable energy, consideration of vapor recovery systems on automobile fueling stations throughout the entire state, emissions inspections for vehicles in Virginia, and additional focus on HAP emission from electric utilities to reduce the metal content of fuels burned.

In addition, Virginia is generally in compliance with the NAAQS for all criteria pollutants with the exception of ozone. Days with strong sunlight and higher temperatures will represent the highest likelihood of elevated ozone concentrations. Although there have been exceedances of the ozone standard between April and October, the peak months having ozone violations in Virginia have been June through August between 9 am and 7 pm. Additional research investigating ozone and respiratory health in Virginia is warranted. In addition, this secondary analysis demonstrated that although weather patterns significantly impact ozone exceedance days, continued focus on ozone precursors will likely improve attainment with the ozone NAAQS. Health data support the need for further analysis and detailed study, however, it appears that the very young (0-4 years of age) and the elderly (>65 years of age) may be the most susceptible to the adverse effects of poor air quality. A comprehensive plan should also be in place to minimize the risks associated with wildfires since they occur occasionally in the Southeastern area of Virginia. During these wildfire events, it is important to make information widely available to residents in areas that may be impacted, such as Hampton Roads.

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